TCE Treatment Pasta-bilities

A layered approach not unlike that of a certain well-known pasta dish may help clean up industrial and military sites, where extensive trichloroethylene (TCE) contamination of soil and water remains one of the most common and widespread legacies. In a patented process called "Lasagna," an electric current forces the contaminant through layers of treatment media, where it is trapped and destroyed.

TCE is a colorless, volatile, nonflammable liquid that is soluble in water and organic solvents. As a solvent, it has found use primarily as a metal degreaser but also in products such as dyes, printing ink, and paint. TCE can eventually make its way into the environment and is prevalent in the water and soil of industrialized nations. Production of TCE in the United States peaked in 1983, but has now declined to under 100,000 tons annually, reflecting a switch to less-toxic chemicals.

When released into the atmosphere, TCE breaks down in a few days. In soil, however, it degrades very slowly over the course of months or years. Moreover, it is often broken down by microbes in a manner that leads to the formation of vinylidene chloride (a suspected human carcinogen) and vinyl chloride (a known human carcinogen). TCE has narcotic properties and when inhaled produces symptoms such as headache, dizziness, and sleepiness. Chronic effects of exposure to TCE include speech and hearing impairments, kidney disease, blood disorders, stroke, anemia, diabetes, and skin rashes. TCE is considered a probable human carcinogen by the U.S. Environmental Protection Agency (EPA), and the National Toxicology Program is considering listing it as reasonably anticipated to be a human carcinogen.

A cost-effective means of battling TCE contamination of soil and groundwater is thus high on public health specialists' remediation technology wish list. Existing methods, which include air sparging, *in situ* bioremediation, soil vapor extraction, and incineration, can be time-consuming and expensive. In recent years, though, the confluence of several events led to the development of the Lasagna method, which has become a viable approach.

Appetizers

In early 1992, a conversation between Monsanto CEO Richard Mahoney and then–EPA Administrator William Reilly about the lack of effective technologies for cleaning contaminated soils resulted in Project Listen, a public meeting in Washington, DC. The meeting was hosted by Reilly and brought together representatives from industry, academia, and government to discuss how to develop fast and cost-effective cleanup technologies for contaminated soil and groundwater. From that jumping-off point, the EPA created the Remediation Technology Development Forum to promote cooperation among its members as they sought to develop innovative technologies.

One of the first companies to take advantage of this opportunity was Monsanto, which was in the process of developing the Lasagna technology. According to Monsanto researcher Sa Ho, Lasagna actually has a pedigree dating from the 1930s. The technique is based on the principle of electro-osmosis, which has been used to draw water from low-permeability soils such as clays, silts, and fine sands. In electro-osmosis, an underground electric field is created between two buried electrodes. Positive ions in the groundwater, which line up on the surface of negatively charged soil particles, are attracted to the cathode, in effect causing the water to migrate from the anode toward the cathode. This process has been used to extract water from railroad beds and riverbank loading areas.

"In the last ten years," Ho says, "people have been thinking about ways to draw contaminated water from soil. Monsanto had been looking for a way to do it *in situ* because of the potential lower cost and less disruption to the environment and reduced worker exposure to hazardous materials. We have lots of technologies for capturing or destroying contaminants [aboveground], but it's very difficult to do so effectively underground because most soils are either very heterogeneous or highly impermeable."

Ho and fellow scientist Phil Brodsky recognized that reagent technologies that destroy contaminants could be combined with electro-osmosis to create an *in situ* approach. He adds, "We realized we could insert a treatment reagent in a thin layer between the electrodes and attack a contaminant as it is pulled through. This concept also led to the idea of using different [treatment media] to treat different contaminants. And it doesn't matter in which direction the contaminants move—we can make them move back and forth by changing the poles of the electrodes." Ho and Brodsky proved the principle in their lab and then Monsanto took it to the EPA forum.

John Kingscott, staff director of the EPA's Technology Innovation Office, says a self-directed action team cochaired by the EPA and private industry was set up to focus on the Lasagna technology. Several organizations chose to participate, including DuPont and General Electric. These two companies formed a consortium with Monsanto and the U.S. Department of Energy (DOE). The EPA signed a cooperative research and development agreement with the consortium to jointly develop the Lasagna process. In return for sharing their skills and resources, DuPont and General Electric were granted the rights to use the Monsanto technology to clean up their own sites. The EPA also offered assistance with the application of hydraulic fracturing technologies. The DOE offered a location for field-testing the technology: a uranium enrichment facility outside Paducah, Kentucky. "This project is a good example of 'demand pull'—an identified need driving the process—rather than a 'supply push,' in which someone develops an interesting technology and then looks for practical uses," Kingscott says.

Monsanto


Monsanto

Cooking up a new cleaning technique. Electrodes and treatment materials are poured into the soil at a treatment site to a depth of 45 feet (left). After installation of Lasagna materials and remediation, monitoring probes and electrode rods are the only visible signs of the process on the site surface (right).

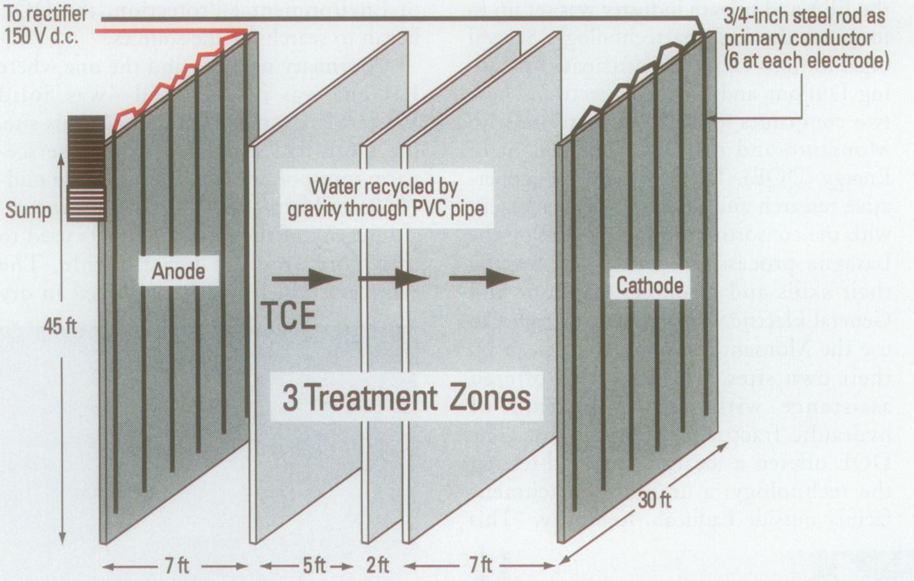
First Course

The Paducah Gaseous Diffusion Plant is located in western Kentucky approximately 16 km west of Paducah and 6 km south of the Ohio River. Owned by the DOE, it has been in commercial operation as a uranium enrichment facility since 1952. A wildlife management area buffers the plant from the surrounding community. In 1988, tests in four private wells outside the plant boundary showed TCE contamination. In conjunction with the EPA and the Kentucky Department of Environmental Protection, the DOE began to search for the sources.

A primary source—and the one where Lasagna was to be tested—was Solid Waste Management Unit 91. At this site, the DOE had simulated worst-case scenario transportation accidents in the mid-1960s and late-1970s to test the structural integrity of the steel containers used to transport uranium hexafluoride. The cylinders, which had been chilled in dry ice and TCE, were dropped onto a concrete and steel pad. The TCE had not only splashed across the area but had leaked into the soil underlying the concrete pit used to chill the cylinders. The total contamination area was 6,000 ft^2 with a total volume of 10,000 yd^3.

The site was attractive for testing because of its low-permeability soils and the existence of a single chlorinated contaminant without heavy metals or radionuclides present. Soil concentrations of TCE ranged from below 1 mg/kg to approximately 1,500 mg/kg, with an average concentration of 84 mg/kg. Groundwater modeling indicated that the concentration of TCE must be reduced to less than 5.6 mg/kg in order for the level at the plant boundary to be less than 5 parts per billion, the maximum concentration allowable by the EPA for drinking water.

In all, twenty alternatives for addressing the Paducah site were evaluated. In the end, it came down to three choices: no action, Lasagna, or *in situ* enhanced soil mixing. The last choice requires a crane-mounted soil-mixing auger system that mixes the contaminated soil with an agent such as hot air or steam and then captures the released contaminants in a shroud. Although this process poses a slightly higher risk to workers and the public because of airborne contamination, the real drawback for the Paducah test was price. The total cost of the soil



Primo! A schematic drawing shows the Lasagna Phase II field test conducted at the DOE Gaseous Diffusion Plant in Paducah, Kentucky, which removed 95–98% of the TCE in contaminated soil. (Illustration: Monsanto)

mixing system was estimated at almost \$3.2 million, while the Lasagna process was estimated to cost under \$2 million.

A first, small test to check the design elements and decontamination efficiency of a very simple Lasagna configuration was completed in May 1995. The test covered an area 15 ft by 10 ft across and 15 ft deep. Two electrodes, each 15 ft by 15 ft, were created, each consisting of eight steel panels driven into the ground side by side and separated by a small gap. To trap the TCE, the panels were fronted with activated carbon held in place by a wick material.

Four treatment zones were devised from columns composed of granular activated carbon encased in a wick drain material and a filter fabric, with a sampling tube running down the length. For each zone, a series of 11 or 12 of these narrow columns were placed in a staggered line to create a "curtain" to trap the TCE. The decontaminated water was handled by a circulation and collection system. Results of this initial test showed that the Lasagna technology removed over 98% of the TCE from the contaminated soil.

Back for Seconds

The second full-scale test lasted one year and was completed in August 1997. This test verified the value of Lasagna as a soil cleanup technology. The test covered an area 21 ft by 30 ft across and 45 ft deep. The major design change from the first test was that the curtains were made of a material intended to degrade the TCE in place rather than simply trap it. In addition, the treatment was extended to a much lower depth.

Three curtains were spaced at variable distances from the electrodes and from each other. This variation was intended to help determine the best spacing as well as to provide information on soil conditions at various stages of treatment. The electrodes and curtain materials were installed by first using a crane to drive 50-ft hollow mandrels enclosing four tubes welded together into the ground. The electrode mandrels were filled with iron filings and Loresco coke, which is sold commercially as a backfill material to protect the cathode against buried metal objects such as pipes and tanks. The curtain material was a slurry of iron filings suspended in wet kaolin clay that had been mixed in a cement mixer and poured into the buried mandrels.

Again, the test proved successful, although this time the effectiveness varied with location. In contaminated areas bracketed by treatment zones, 95–98% of the TCE was removed. Based on these tests, the researchers estimated that for a typical one-acre site with contamination from 15 ft to 45 ft deep, the cost of the Lasagna technology would range from approximately \$45 to \$80 per yd^3.

Varying the Recipe

Lasagna is now being commercialized and will be used to finish the work it started at Paducah. Refinements can still benefit the process, however, according to Ho. In particular, he says, simpler and faster methods for installing electrodes and treatment zones could significantly lower the cost of the treatment. Important as well are operational concerns such as effective underground water management and accurate assessment of the extent of cleanup as a function of time.

The Lasagna technology may be installed either vertically, as at Paducah, or horizontally in a process that uses hydrofracturing to create the layers. The latter installation may be more applicable for deeper contamination. Organic, inorganic, or mixed-waste contamination may be treated in different permutations. For example, some treatment zones could trap metals and some could degrade organics, or identical treatment zones could contain mixed treatment materials to both trap metals and degrade organics. Alternatively, the metals could first be immobilized by adsorption/chelation, then microbes could be introduced to destroy the organics. Researchers anticipate many applications, someday making up a veritable cookbook of variations on the basic Lasagna recipe.

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Suggested Reading

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